

625-20-006

Project completion

Atmosphere-Ocean Dynamics and Tracer Transport

PI: Roberto Mechoso, UCLA



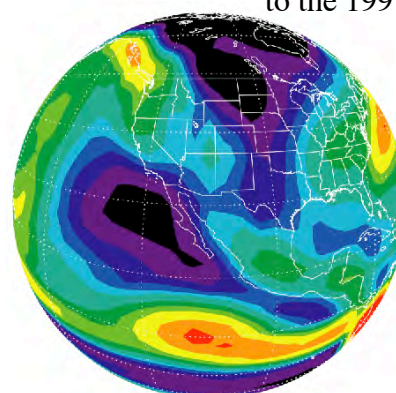
Atmosphere-Ocean Dynamics and Tracer Transport

PI: C. Roberto Mechoso, UCLA

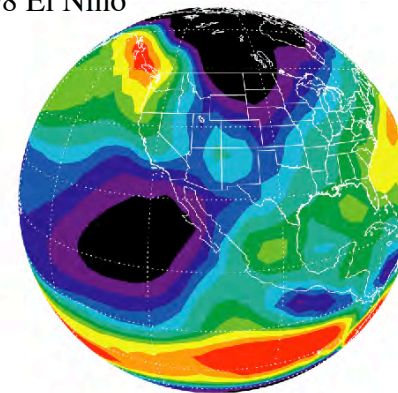
Objective

- Develop Earth System Modeling Framework (ESMF) components for better understanding of the El Niño/Southern Oscillation.
- Generalize and extend data broker service for coupling atmosphere and ocean models together
- Test and Evaluate ESMF services

Global precipitation changes due to the 1997-98 El Niño



Control



1997-98 El Niño

Approach

- Complete development of data broker service prototyped under previous award
- Participate in design of ESMF to infuse lessons learned from data broker prototype
- Convert Atmospheric General Circulation Model (AGCM), Ocean General Circulation Model (OGCM), and Hybrid Parallel Ocean Program (HYPOP) to use ESMF services
- Test ESMF services and ease of use compared to native implementation

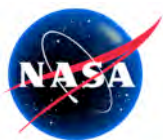
Co-I's

John Baumgardner, DOE/Los Alamos National Lab,
Dimitris Menemenlis, JPL, George Philander, Princeton

Key Milestones

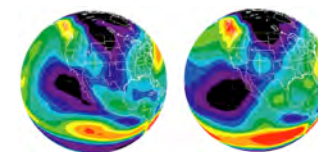
- | | |
|---|-------|
| • Procedures for integrating the AGCM/OGCM with the ESMF | 12/02 |
| • First code improvements (on AGCM) | 4/03 |
| • Distributed Data Broker development completed | 7/03 |
| • OGCM converted to hybrid vertical coordinates and demonstrated without loss of performance | 1/04 |
| • Full Interoperability - Couple AGCM and HYPOP into the ESMF framework | 4/04 |
| • Customer delivery - Analyze El Niño prediction capability of AGCM/HYPOP/Massachusetts Institute of Technology OGCM. | 12/04 |

TRL_{in} = 4



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Description

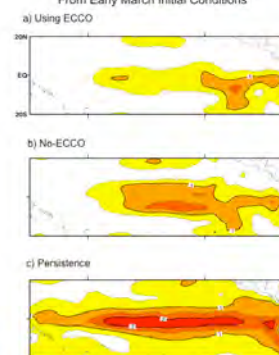
- Generalize and extend data broker service for coupling atmosphere and ocean models together
- Test and Evaluate ESMF services

Objective

- Develop Earth System Modeling Framework (ESMF) components for better understanding of the El Niño/Southern Oscillation.

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Standard Deviation of DJF Forecast Error
From Early March Initial Conditions

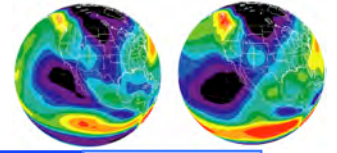
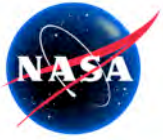


Using ESMF compliant components with improved parameterizations, for forecasts initiated in March, those obtained using initial conditions from the JPL/ECCO project show smaller root mean square errors in the equatorial Pacific than the forecasts from initial conditions from the model fields without data assimilation and the persistence forecasts.

Accomplishments

- Defined the gridded components and coupler for the ESMF compliant UCLA Earth system model application component.
- Upgraded the parameterization of the planetary boundary layer (PBL) used in the Atmospheric General Circulation Model (AGCM) to a version with multiple layers.
- The new code runs 5-7% slower on Chapman than the code used in previous milestones
- Upgraded POP to a near global domain (excluding both polar regions) and with the same resolution and domain as the MIT OGCM
- Coupled POP to the UCLA AGCM (with upgraded Planetary Boundary Layer parameterization from Milestone-F)
- Successfully integrated the coupled system out to 270 days, and produced realistic science results (see figure)
- Made codes publicly available via the Web
- Made the UCLA AGCM model ESMF compliant.
- Used the ESMF to couple the UCLA AGCM to the LANL POP model and the MIT OGCM model.
- Initialized each coupled system with time-evolving ocean circulation data products produced by the consortium for Estimating the Circulation and Climate of the Ocean (ECCO).
- Successfully integrated each coupled system out to 270 days with a 6 hour coupling interval and negligible overhead.
- Obtained very encouraging results with respect to forecast skill.
- Demonstrated ESMF functionality by analyzing El Niño prediction capability of the UCLA Atmospheric General Circulation Model (AGCM) coupled to the LANL Parallel Ocean Program (POP) and the MIT Oceanic General Circulation Model (OGCM).
- Initialized coupled systems with ocean circulation data products produced by the consortium for Estimating the Circulation and Climate of the Ocean (ECCO).
- Completed User's Guide/Maintenance manual.
- Made documented source code publicly available via the Web.

Impact (see following charts)



625-20-006

Impact Charts

Atmosphere-Ocean Dynamics and Tracer Transport

Akio Arakawa (1): AGCM; Cabriel Cazes-Boezio; (1, 7): AGCM PBL, Coupled GCM;

C. Roberto Mechoso (1): P. I.;

Chris Hill (3): MIT OGCM: Phil Jones (4): POP;

Dimitris Menemenlis (5): MIT OGCM, ECCO; George Philander (2): Coupled GCM

Joseph A. Spahr (1): ESMF; Slujia Zhou (6): ESMF

(1) *Department of Atmospheric and Oceanic Sciences, University of California Los Angeles*

(2) *Program in Atmospheric and Oceanic Sciences, Princeton University*

(3) *Department of Earth, Atmospheric and Planetary Sciences, MIT*

(4) *Theoretical Fluid Dynamics Group, Los Alamos Natural Laboratory*

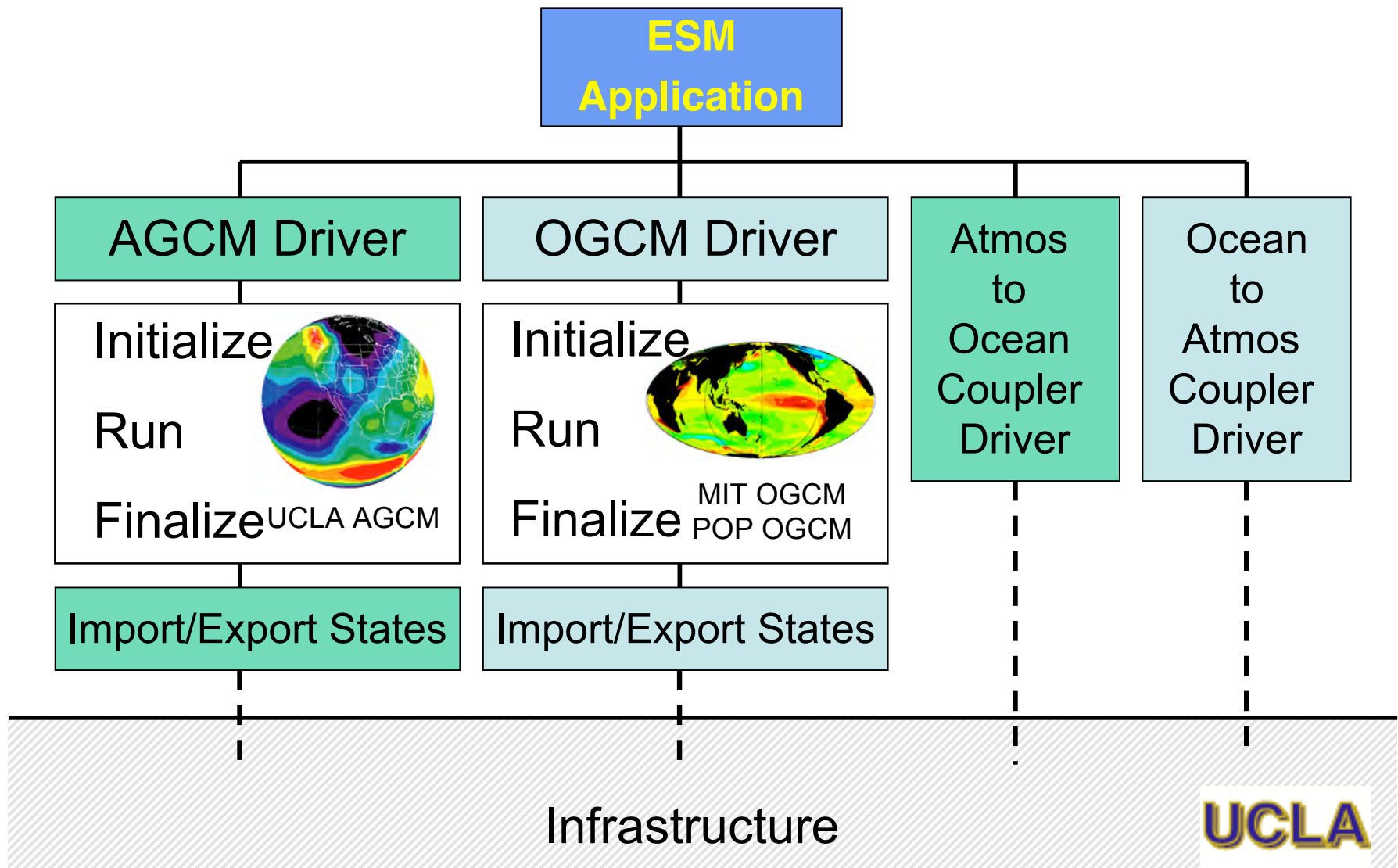
(5) *NASA/Caltech Jet Propulsion Laboratory*

(6) *Software Integration and Visualization Office, NASA GSFC and Northrop Grumman*

(7) *On leave from Fluid Mechanics and Environmental Engineering Institute, U. of Uruguay*

Sponsor: NASA Earth Science Tech. Off. (ESTO), NOAA PACS

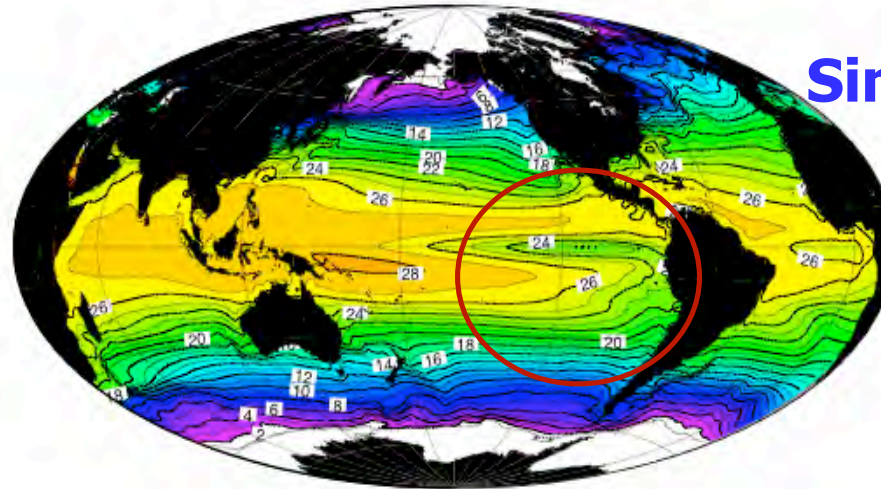
Coupled Atmosphere-Ocean Application in ESMF- Superstructure



UCLA-AGCM globally coupled to MIT-OGCM

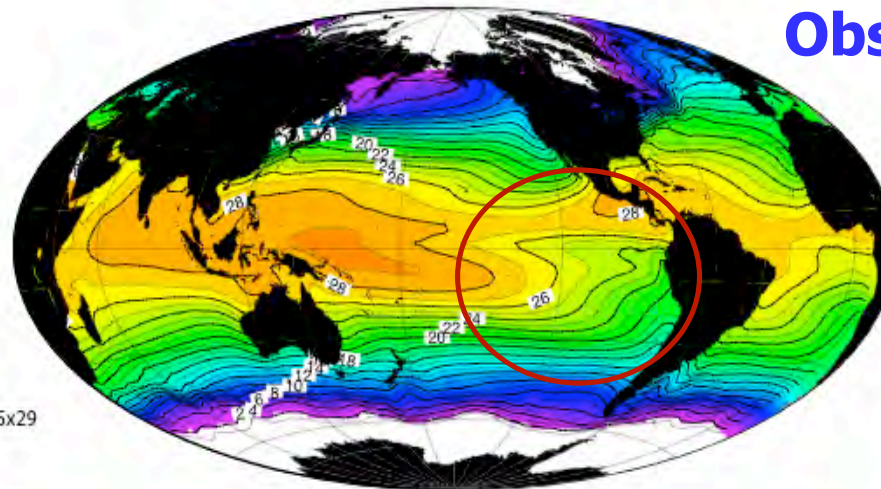
High-atmospheric resolution (2.5X2)

Annual Mean SST Simulation



Simulated annual mean SST

Annual Mean SST: Reynolds analysis



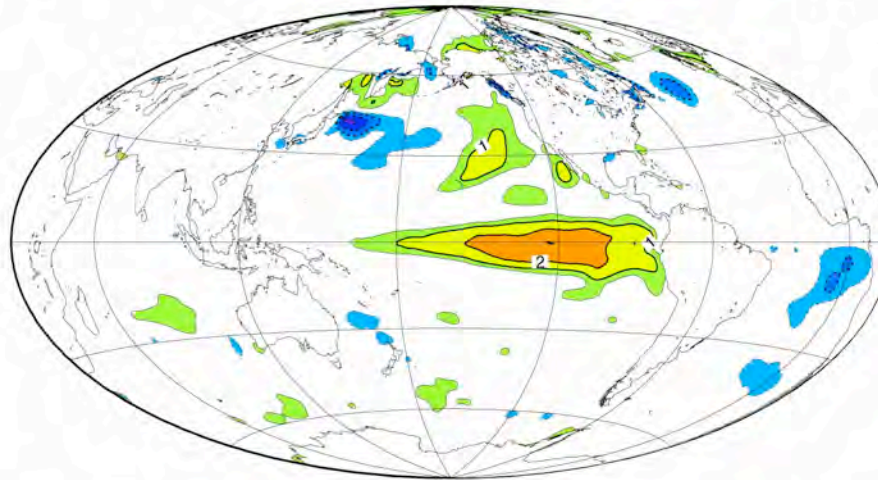
Observed annual mean SST

UCLA AGCM 8.0 2x2.5x29
MIT OGCM Global

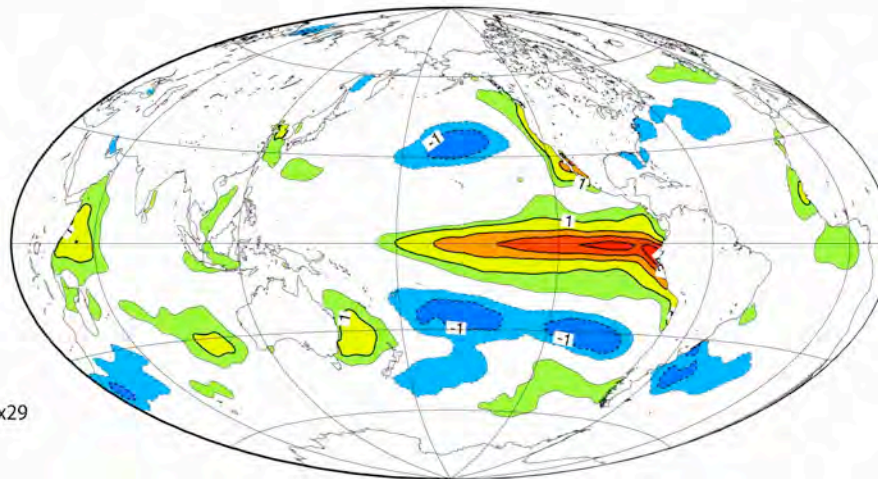
- Cold tongue is asymmetric relative to the Equator. Equatorial West-East SST gradient is realistic.
- Double ITCZ still exists, but SST errors are smaller than with low-resolution

DJF 1997 Forecast from March 5, 1996

DJF 1997 SST anomaly from March 5 initial conditions (ECCO)



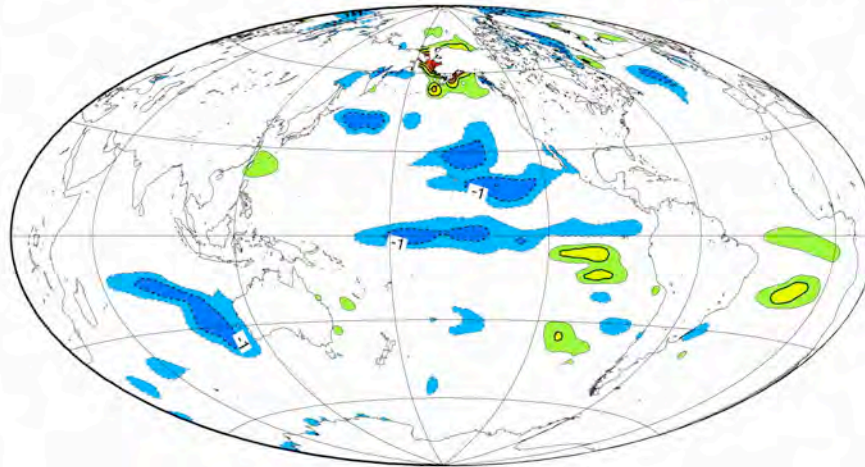
Reynolds analysis



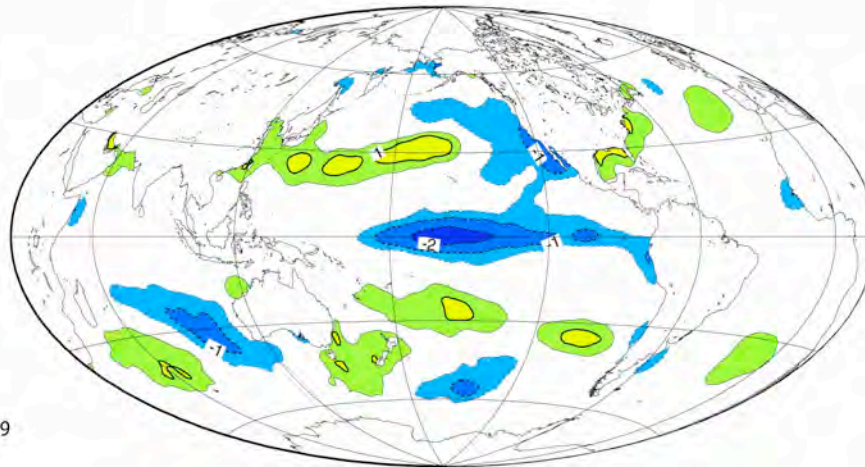
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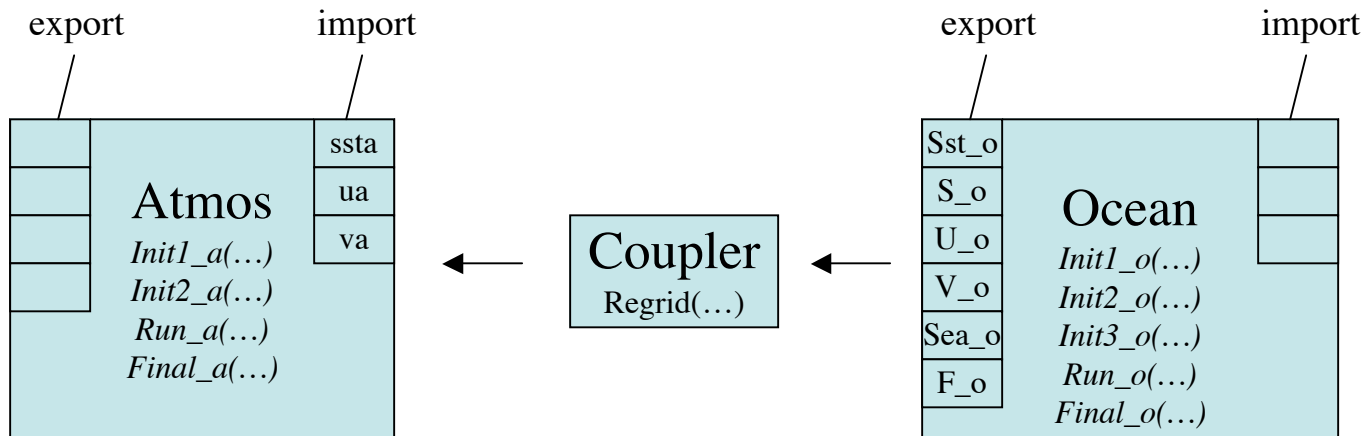
Reynolds analysis



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Work towards a Generic Coupler

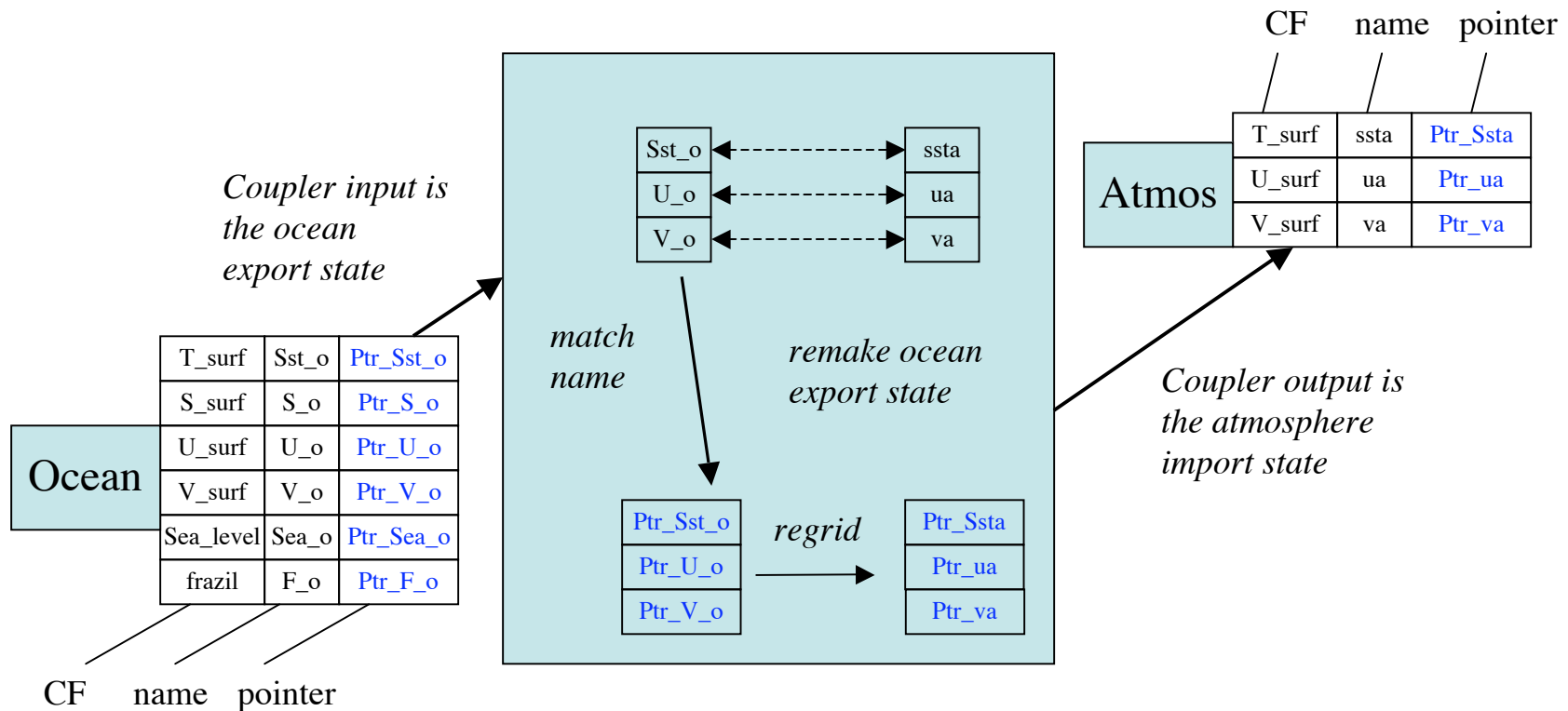
(e.g., Ocean and Atmosphere)



1. Function names in model components can be different.
ESMF's solution:
 - Use three standard functions with a stage option, *initialize*, *run*, and *finalize*
 - Use a function registration service, *setEntryPoint* and *setService*
2. The names (numbers) of import variables of a "use" component are different from those of export variables of a "provide" component.
ESMF does not address this issue

Generic Coupler: Design

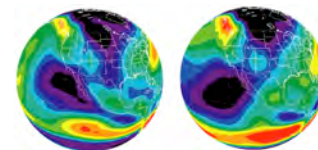
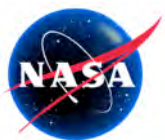
Registration based on UCLA-UCB/DDB
Data transfer and regridding based on ESMF



*The Generic Coupler perform interpolations only.
(CF: Net CdF Climate and Forecast Metadata Convention)*

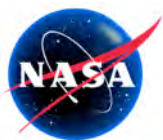
SUMMARY

- The ESMF shows great promise of facilitating multidisciplinary research.
- The UCLA AGCM was coupled to the MIT OGCM and LANL POP using ESMF services.
- Much more work with the ESMF is needed for debugging, increased capability and user friendliness.
- Model codes integrated into the ESMF require maintenance if the framework is to become a standard for Earth System Modeling.
- The coupled atmosphere-ocean model shows skill in ENSO prediction from six months in advance. The skill is higher for the UCLA AGCM/MIT OGCM combination with ECCO initial conditions for the ocean
- Development of a generic coupler by NASA/UCLA started in order to simplify the ESMF use in serial and concurrent modes.



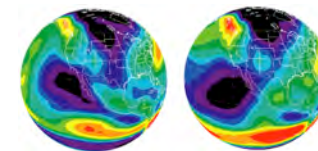
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Achievement Quads



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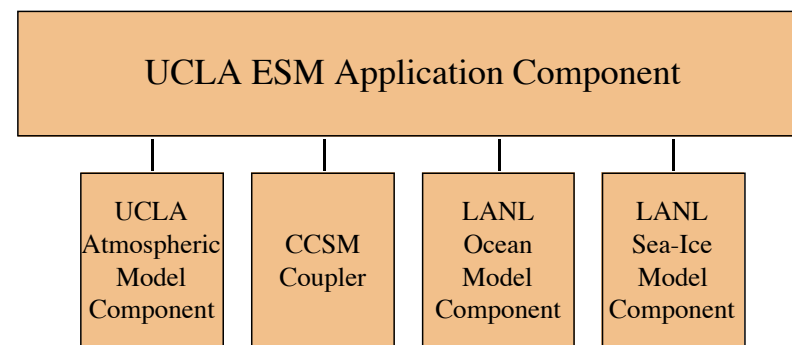
PI: C. Roberto Mechoso, UCLA

Description

- Generalize and extend data broker service for coupling atmosphere and ocean models together
- Test and Evaluate ESMF services

Objective

- Earth System Modeling Framework (ESMF) components for better understanding of the El Niño/Southern Oscillation.



The CCSM coupler will understand ESMF objects and services and will use the 'hub and spoke' strategy to handle all data conversion/transfer among gridded components.

Accomplishments

- Defined the gridded components and coupler for the ESMF compliant UCLA Earth system model application component.
- Developed
 - an updated Requirements Document
 - an Interface Control Document defining the interface between ESMF and the AGCM/OGCM.
 - a Test Plan/Procedures for integrating the AGCM/OGCM with the ESMF.

Key Milestones (11 milestones total)

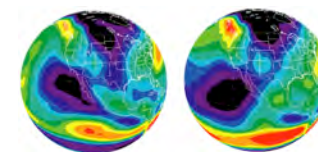
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TRL=4_{in}-4_{current}



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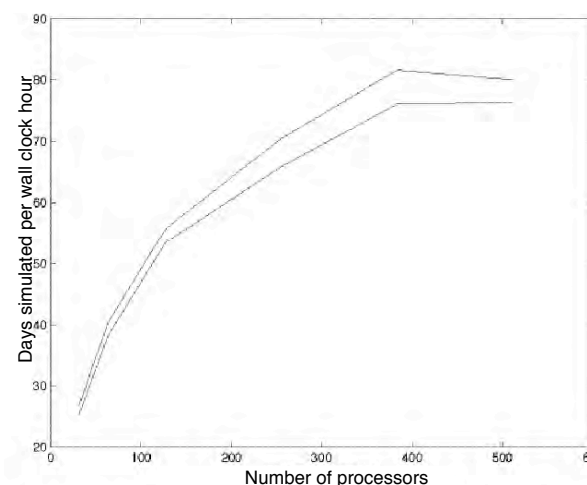
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Simulated days per wall clock hour, for the UCLA AGCM on the SGI 3000, chapman [28 vertical layers, 2° latitude, 2.5° longitude]. The higher curve is with a single layer PBL. The lower curve is with a four layer PBL.

Accomplishments

- Upgraded the parameterization of the planetary boundary layer (PBL) used in the Atmospheric General Circulation Model (AGCM) to a version with multiple layers.
- The new code runs 5-7% slower on Chapman than the code used in previous milestones

Key Milestones (11 milestones total)

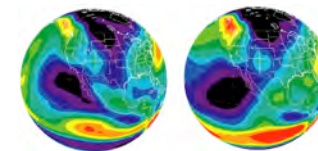
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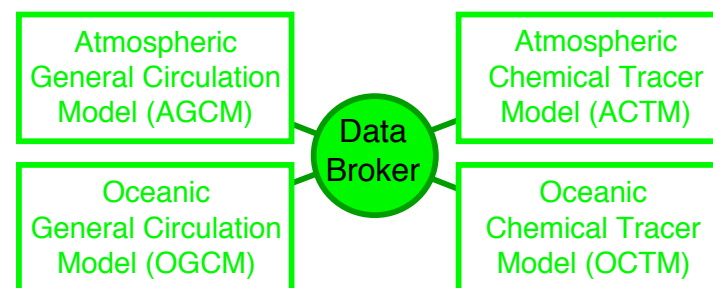
Description

- Generalize and extend the UCLA Distributed Data Broker (DDB) service for coupling atmosphere and ocean models together
- Test and Evaluate ESMF services

Objective

- Earth System Modeling Framework (ESMF) components for better understanding of the El Niño/Southern Oscillation.

UCLA Earth System Model



*Completed development of
the Distributed Data Broker*

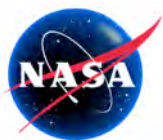
Accomplishments

- Upgraded the Distributed Data Broker to:
 - Support both PVM and MPI communications.
 - Check input arguments for consistency and valid range.
 - Verify the configured meta-machine and data flow matrix at the end of registration.
 - Support 32 and 64 bit addressing modes.
 - Have a simplified user interface.
 - Have revised documentation with clarified diagnostic output.

Key Milestones (11 milestones total)

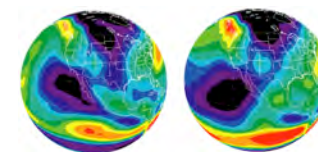
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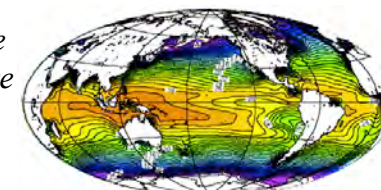
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UCLA Atmospheric General Circulation Model (AGCM)

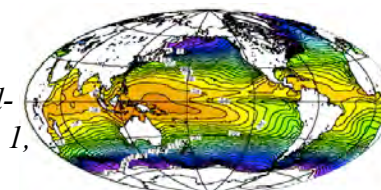
Data Broker

LANL Parallel Ocean Program (POP)

Sea surface temperature for the month of December 1997 from initial conditions corresponding to June 1, 1997.



Coupled model result



Observed data

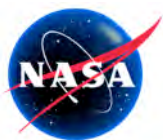
Accomplishments

- Upgraded POP to a near global domain (excluding both polar regions) and with the same resolution and domain as the MIT OGCM
- Coupled POP to the UCLA AGCM (with upgraded Planetary Boundary Layer parameterization from Milestone-F)
- Successfully integrated the coupled system out to 270 days, and produced realistic science results (see figure)
- Made codes publicly available via the Web

Key Milestones (11 milestones total)

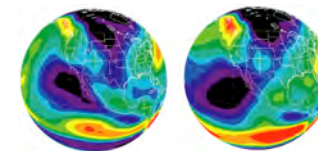
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Used ESMF to couple the UCLA AGCM to the LANL POP model and the MIT OGCM model.

UCLA Atmospheric General Circulation Model (AGCM)

ESMF 2.01

LANL Parallel Ocean Program (POP)

UCLA Atmospheric General Circulation Model (AGCM)

ESMF 2.01

MIT Oceanic General Circulation Model (OGCM)

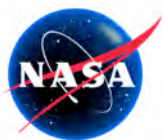
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- Obtained very encouraging results with respect to forecast skill.

Key Milestones (11 milestones total)

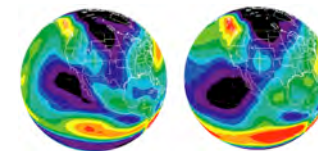
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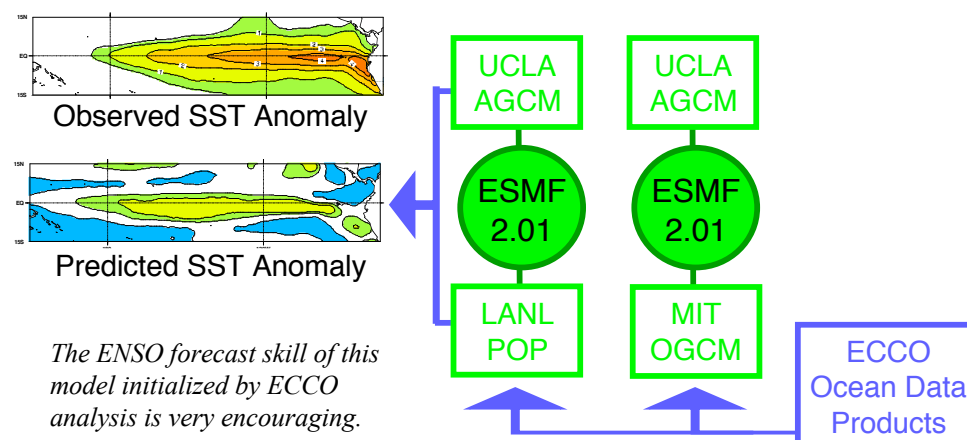
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Accomplishments

- Demonstrated ESMF functionality by analyzing El Niño prediction capability of the UCLA Atmospheric General Circulation Model (AGCM) coupled to the LANL Parallel Ocean Program (POP) and the MIT Oceanic General Circulation Model (OGCM).
- Initialized coupled systems with ocean circulation data products produced by the consortium for Estimating the Circulation and Climate of the Ocean (ECCO).
- Completed User's Guide/Maintenance manual.
- Made documented source code publicly available via the Web.

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